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(54) Apparatus for capturing subsea leakage of oil and gas

(57) A liquid-gas separator for capturing oil and gas flowing uncontrollably from a sea floor well blowout includes a vessel (12) which is placed near the sea floor over the blowout. Gas released from the oil is separated in the vessel and conducted away (72). The captured oil, freed of a large amount of dissolved gas, is then desirably conveyed to a floating storage vessel (80) where further released gas is separated and disposed of. The oil is removed from the storage vessel as desired.

Both the separator and the storage vessel have bottoms open to the sea so that the oil and gas are captured and stored by water displacement.

FIG.6

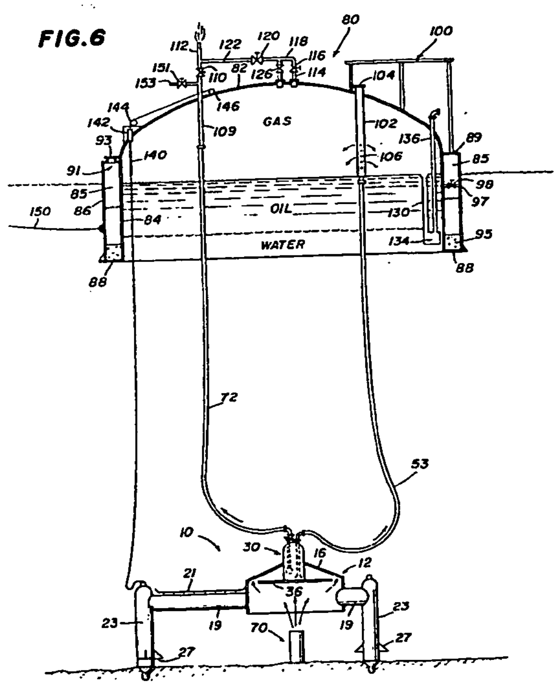

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FIG.3

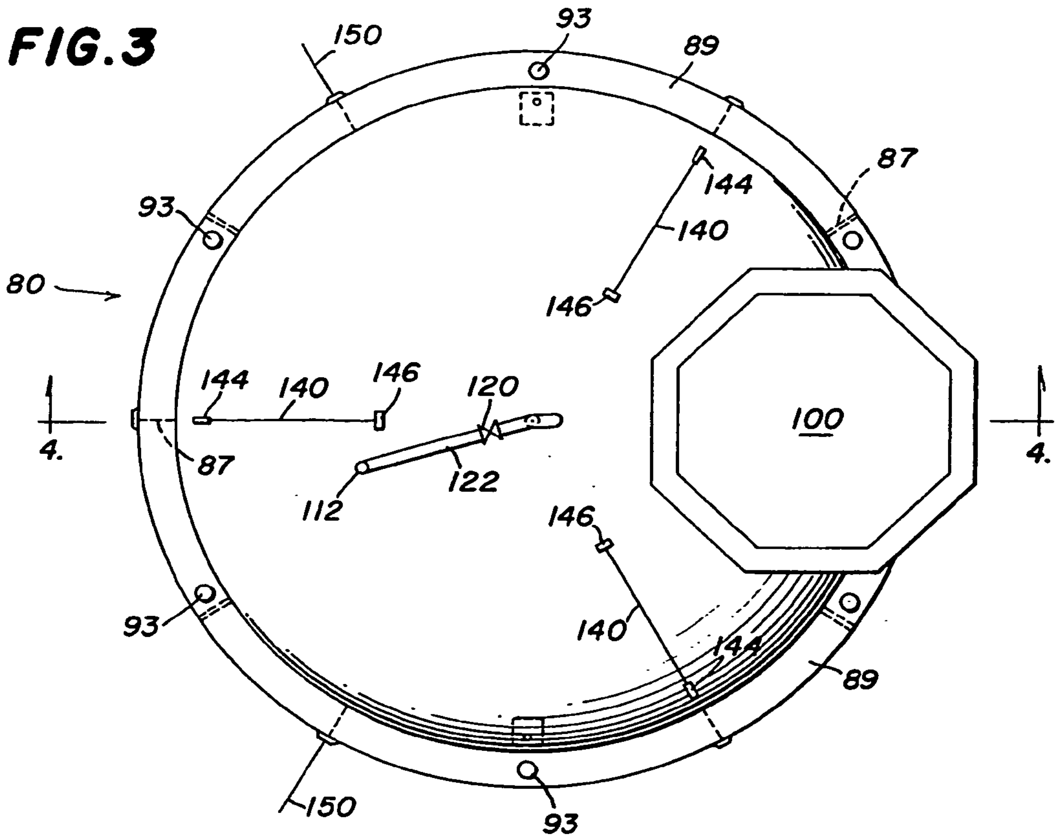
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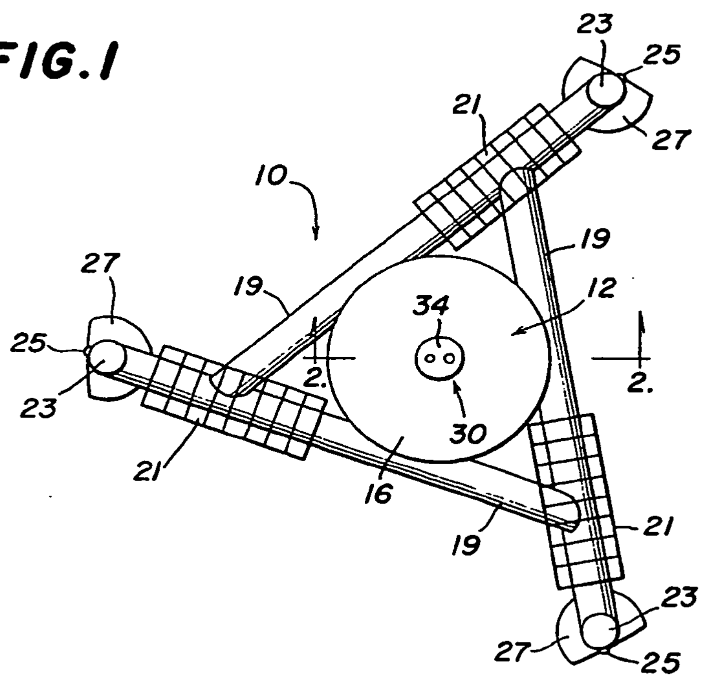
FIG.1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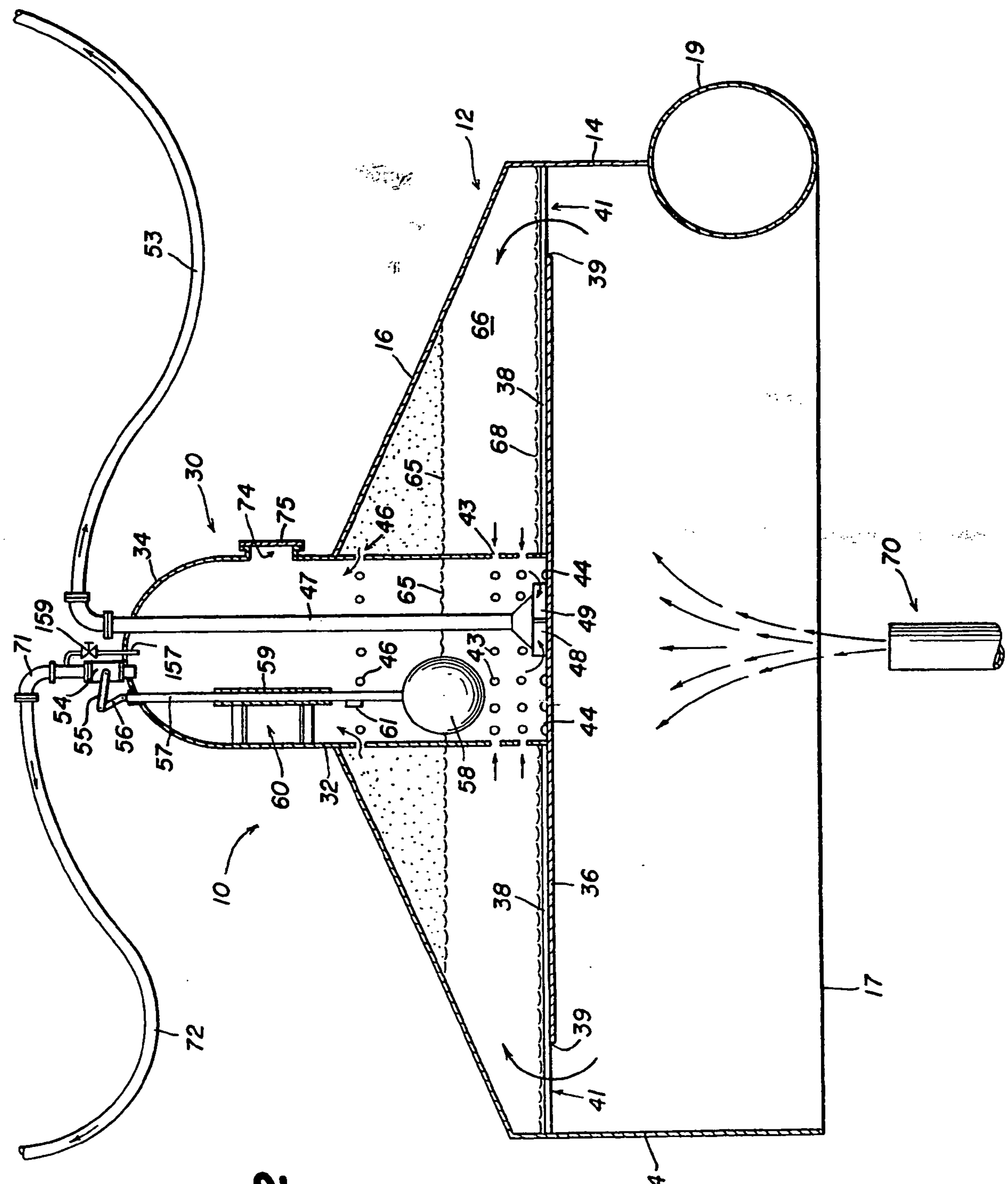

FIG.2

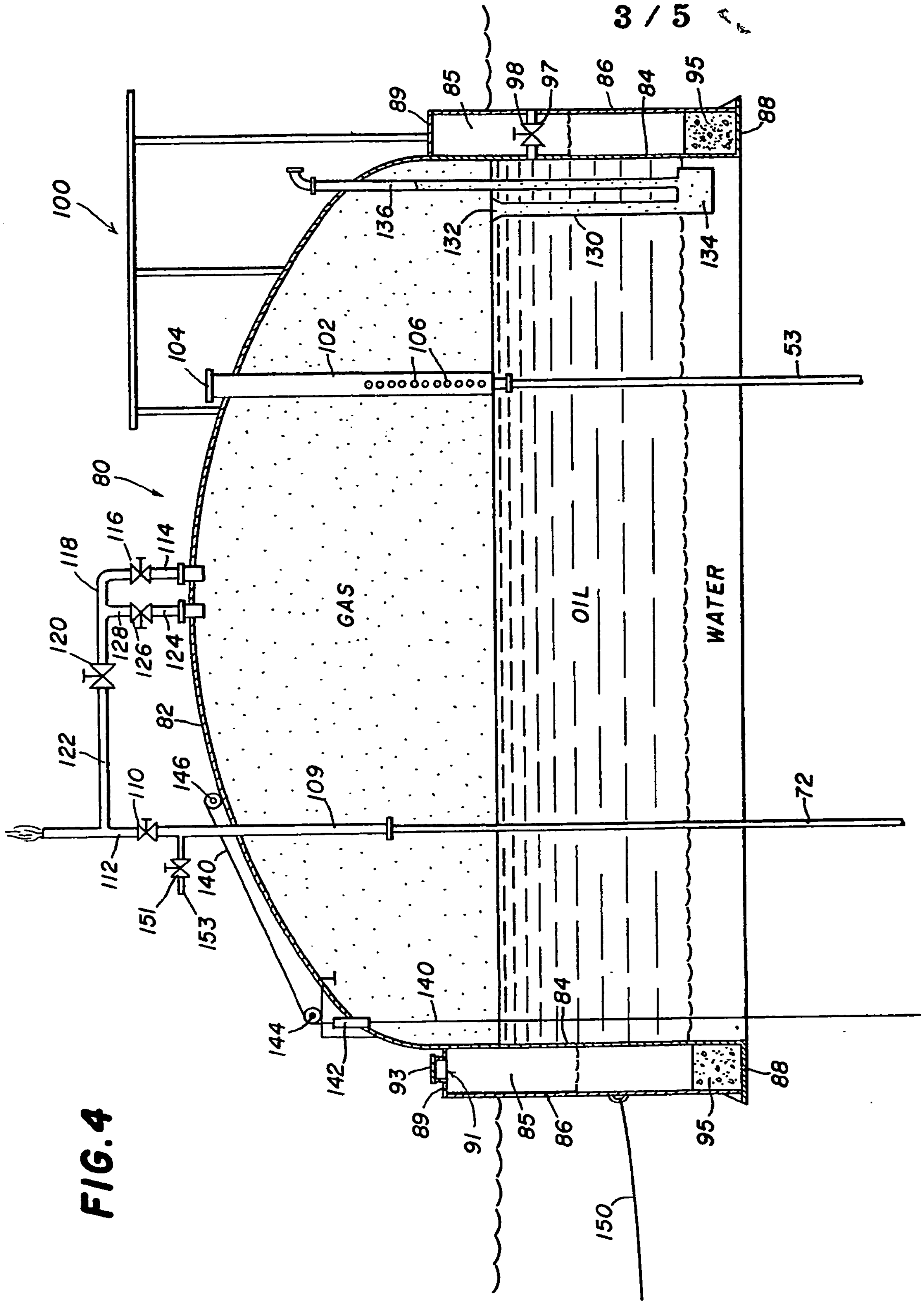
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FIG. 4

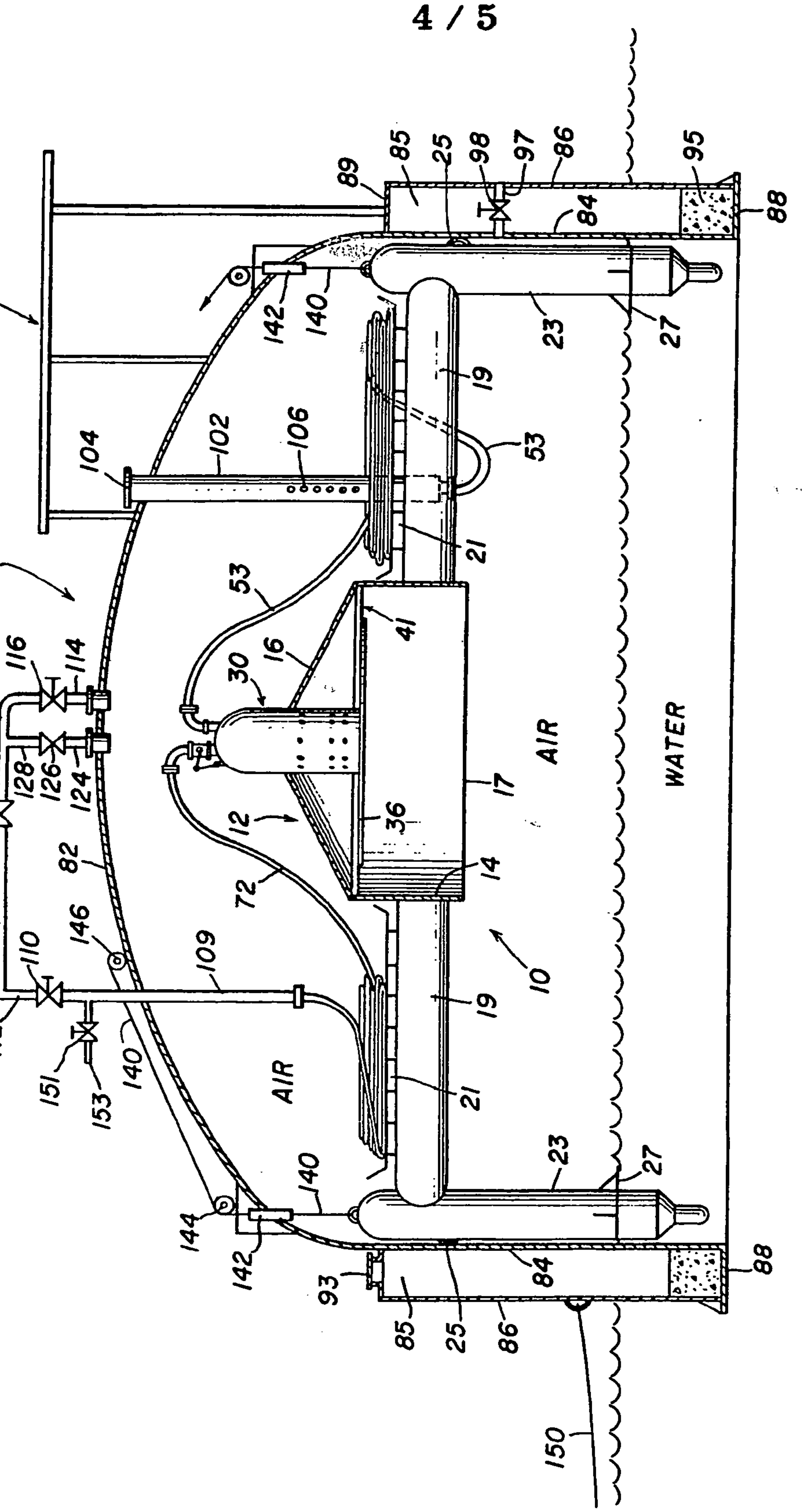
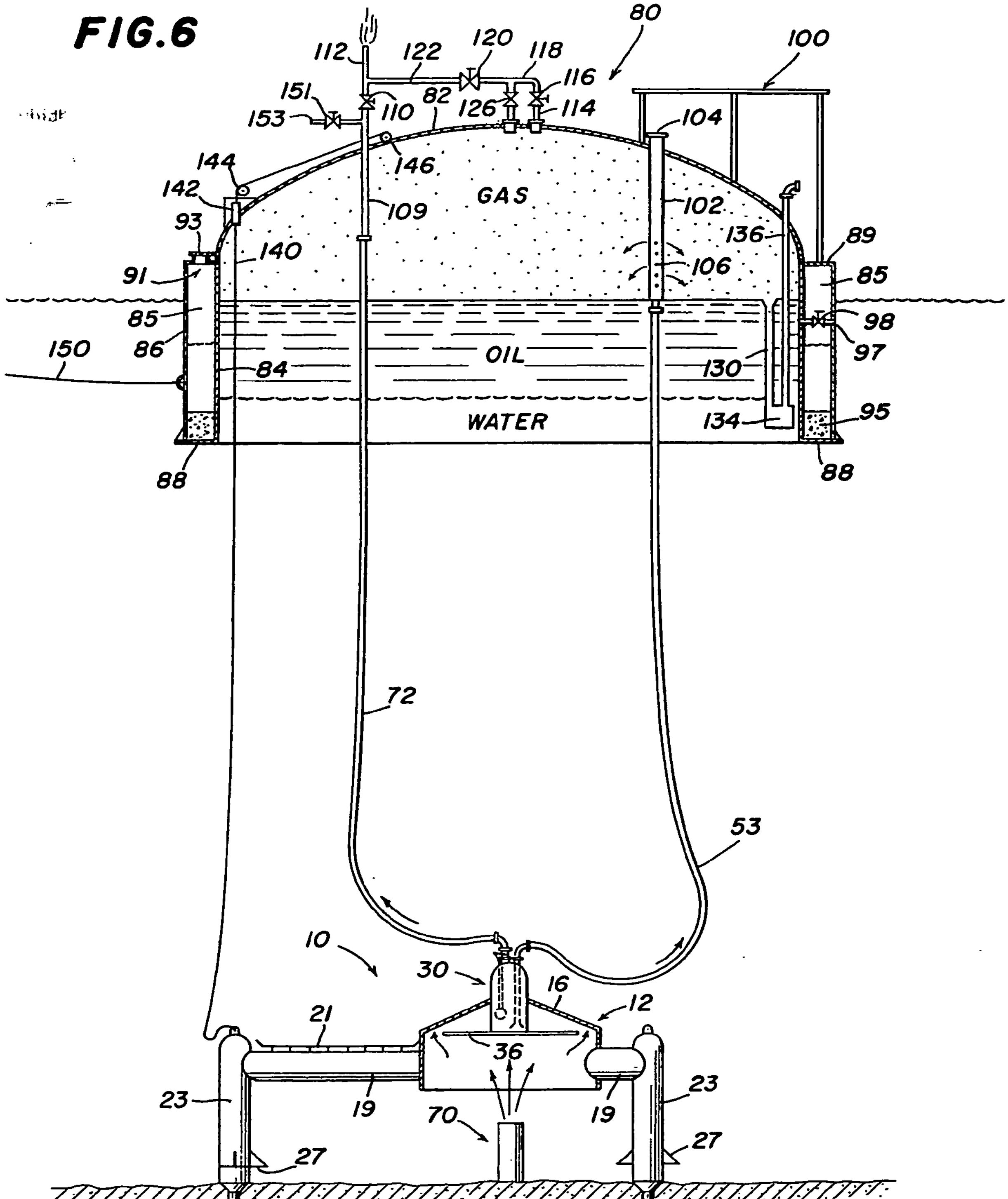


FIG.5

FIG.6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SPECIFICATION

Improvements in or relating to apparatus for and a method of capturing oil and gas

This invention relates to apparatus and methods for capturing and storing oil and gas, such as oil and/or gas flowing uncontrollably from an offshore well.

Oil exploratory and prduction wells are drilled offshore in many places around the world. These wells are drilled from both floating vessels as well as platforms resting on the sea floor. Occasionally, there is a well blowout and oil, containing gas under high pressure, uncontrollably flows from the well. The escaping gas is very flammable and may easily catch fire from a spark or static electricity at the drilling rig. However, most of the oil does not burn in such a blowout and, as a result, it floats on the sea surface until it washes onto a beach, or it is dispersed, for example when sprayed with dispersants.

When the escaping gas catches fire the intense heat very easily melts down the drilling rig and this can result in collapse of the well riser or similar pipe extending from the sea floor to the sea surface. Upon collapse of the pipe all control over flow from the well is quite often lost, resulting in uncontrollable flow from the well mouth at or near the sea floor. Plugging such a well blowout is very difficult, even after the fire is extinguished and may require the drilling of one or more diversionary wells through which drilling mud, or cement or other material can be pumped into the sub-sea floor or subterranean formation, from which the oil flows, to plug or block the fissures against further oil flow.

Drilling diversionary wells is time consuming and may take two or three months, during which time oil and gas flows uncontrollably from the first well that has experienced the blowout. Escape of the oil and gas is undesirable, not only because it contaminates the sea and shore, but also because it constitutes loss of a very valuable raw material needed as a fuel and source of petrochemicals.

Previously, efforts have been made to capture the oil uncontrollably flowing from an offshore blowout so that the oil would not be lost and wasted, or contaminate the environment, while trying to stop the oil flow.

It is believed that one way which was previously tried to capture escaping oil from a sea floor well blowout used a dome or concave container which was placed above the well mouth. The idea, apparently, was to capture the oil beneath the dome at the sea floor and then convey the oil from the dome interior through a pipe extending to the sea surface. This effort failed, however, and while the reason is not certain it is believed that the escaping oil released large amounts of gas dissolved in the oil under a pressure which was greater in the earth than the hydrostatic pressure at the sea floor. The freed gas flowing through the pipe, in a ratio of as much as 20 parts by volume of gas to one part by volume of oil, produced a very efficient gas pump which emptied the oil from the dome and then pumped sea water, mixed with oil, through the pipe. Capture of oil in this way was thus thwarted by the lifting or pumping action of the fast rising gas.

There is thus a need for apparatus that will satisfactorily capture and store oil and gas flowing from an undersea well.

According to one aspect of this invention there is provided a liquid-gas separator for use in the offshore capture near the sea floor of uncontrolled flowing oil containing dissolved gas under high pressure which is released from the oil, comprising: a separator vessel comprising a shell, having a substantially open bottom, enveloping or surrounding a volume from the shell top to open bottom; a gas removal conduit communicating with an opening in the upper part of the shell through which separated gas can be selectively withdrawn from the vessel; an oil withdrawal conduit having a lower end within the volume inside the shell and substantially below the gas opening and extending upwardly through the shell; a valve in the gas removal conduit for regulating withdrawal of gas so that an interface between oil and gas in the vessel can be maintained within a predetermined vertical displacement, above the lower end of the oil withdrawal conduit; and means attached to the vessel for supporting the vessel near the sea floor above a source of uncontrolled flowing oil containing dissolved gas.

According to another aspect of this invention there is provided an offshore oil storage apparatus comprising: a floatable storage vessel having positive buoyancy at all times in normal operation comprising a shell, having a substantially open bottom, enveloping or surrounding a volume from the shell top to open bottom; a conduit for delivering a mixture of oil and gas to the storage vessel interior; a conduit for withdrawal of oil from the vessel interior with the vessel floating on water and containing a layer of oil floating on the water and with gas above the oil layer; and a conduit for withdrawal of gas from the vessel interior.

According to a further aspect of this invention there is provided an offshore liquid-gas separator, collector and storage unit, comprising in combination: (A) a floatable storage vessel having positive buoyancy at all times in normal operation comprising a shell, having a substantially open bottom, enveloping or surrounding a volume from the shell top to open bottom; a conduit for withdrawal of oil from the vessel interior with the vessel floating on water and containing a layer of oil floating on the water and with gas above the oil layer; and a conduit for withdrawal of gas from the vessel interior and (B) a liquid-gas separator vessel comprising a shell, having a substantially open bottom, enveloping or surrounding a volume from the shell top to open bottom; a gas removal conduit communicating with an opening in the upper part of the shell through which separated gas can be selectively withdrawn from the vessel and delivered to a disposal means on the floatable storage vessel, a valve in the gas removal conduit for regulating withdrawal of gas so that an interface between oil and gas in the vessel can be maintained within a predetermined vertical displacement above the lower end of the oil withdrawal conduit; and an oil withdrawal conduit

having a lower end inside of the shell and substantially below the gas opening and extending upwardly through the shell and into communication with the storage vessel interior.

It has been found that oil and gas uncontrollably flowing from a sea floor well can be captured if it is gathered under conditions which provide for separation of much of the gas, released from the oil, from the oil near the well mouth or sea floor, followed by delivery of the separated gas through a first conduit to a suitable destination and separate delivery of the oil, from which most gas has been removed, through a second conduit to a destination.

The described oil-gas capture and separation system can be readily effected by the liquid-gas separator provided by the subject invention.

The escaping oil, and gas released from the oil, flow up into the separator vessel when it is placed over a well mouth from which the oil is escaping. The vertical fluid velocity is thus stopped and controlled in this way. The gas collects in the vessel above a layer of oil in the vessel. The free gas is thus captured at the approximate pressures at the sea floor and is not permitted to expand freely in an oil-water environment. The layer of oil, in turn, floats on water which can enter and leave the vessel freely through the open bottom.

The liquid-gas separator desirably includes a substantially horizontal deflector plate beneath, and spaced downwardly from, the lower end of the oil withdrawal conduit. The deflector plate, furthermore, should generally be positioned above the vessel open bottom. One purpose of the deflector plate is to facilitate evolution and separation of gas from the oil by having the fluid strike the deflector plate and flow radially and then upwardly around the edge of the deflector plate into the upper part of the vessel. The size of the annular flow area between the vessel shell and the deflector plate is such that the fluid velocity is slowed to a fraction of the well head velocity. Another purpose of the deflector plate is to provide a quiescent environment above it for the gas-oil separation to continue.

To facilitate accumulating the separated gas, the separator vessel can be provided with a centrally positioned gas receiving receptacle extending above the vessel top. The receptacle is herein considered part of the separator vessel. In one specific embodiment, the gas receiving receptacle can have a circular cylindrical wall which can extend through the top of the vessel, and a roof supported by the receptacle wall. The bottom of the receptacle can be open to the vessel interior or it can be closed such as by attaching the deflector plate to the receptacle wall. However, the receptacle has means which permits flow of separated gas from the vessel interior to the receptacle interior. Such means can constitute ports in the receptacle wall. Since the receptacle is intended to accumulate the separated gas, it is generally advantageous to have the gas removal conduit communicate with the upper space of the receptacle interior.

The liquid-gas separator is advisably made so that it will float on the sea surface. It, accordingly, is preferably provided with suitable ballast means and buoyancy means, attached to the vessel, to give it floatable stability. The separator can thus be towed to a well blowout and then lowered by suitable means to a position near the sea floor. An inlet is desirably included in the vessel top so that air may be controllably added to the vessel through the gas removal conduit as it is being submerged.

Furthermore, additional buoyancy control may include floodable horizontal tubular members attached to the vessel.

Vessel support legs can extend downwardly from the vessel, and specifically from the tubular members, so that the vessel can be supported near, but above, the sea floor by the legs which extend downwardly to, and rest on, the sea floor. The legs can be hollow tubular columns which also function as floodable buoyancy chambers. Supporting the separator, as by legs, above the sea floor is often desirable because debris from the blowout is often resting on the sea floor around the well mouth so that by means of the legs and tubular members, the separator can straddle the wreakage and debris from the blowout.

Although the liquid-gas separator may have many shapes, it is now preferred that the vessel have substantially vertical walls, desirably in the form of a cylindrical shell. The vessel wall can support a suitable roof, such as a conical or double curved or domed roof.

The offshore oil storage apparatus vessel of the invention which can be used with the previously described liquid-gas separator, desirably has a substantially vertical circular cylindrical wall and roof supported by the wall. The wall can have buoyancy chambers to which ballast can be added as needed to provide floatable stability.

Although the described offshore oil storage apparatus has other uses, it is desirably used in combination with the previously described liquid-gas separator to thereby form an offshore liquid-gas separator, collector and storage unit.

The liquid-gas separator, in such a combination apparatus, is desirably attached to the floatable storage vessel by means which can lower and raise the separator in water. Furthermore, the liquid-gas separator is advantageously designed so as to be substantially nestable within the floatable storage veessel. With the separator nested in the floatable storage vessel, the entire apparatus can be floated to a well blowout. Then the floatable storage vessel can be anchored and the separator can be lowered, such as by wire rope attached to winches, until the separator rests on the sea floor over and above the well mouth. The apparatus can then be operated in its intended manner to separate the liquid and gas in the separator, feed the liquid (oil) to the storage vessel, and deliver the separated gas to a flare, such as one on the storage vessel.

In order that the invention may be more readily understood, and so that further features thereof may be appreciated the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a plan view of one embodiment of a liquid-gas separator according to the invention;

Figure 2 is a vertical sectional view taken along the line 2-2 of Figure 1

Figure 3 is a plan view of one embodiment of a floatable storage vessel according to the invention;

Figure 4 is a vertical sectional view taken along the line 4-4 of Figure 3;

Figure 5 is a side view, partially in section, showing the separator of Figures 1 and 2 nested inside of the floating storage vessel, shown in Figures 4 and 5 and the complete apparatus floating on water; and

Figure 6 shows the liquid-gas separator supported by the sea floor above a well blowout with the floating storage vessel.

So far as is practical, the same or similar elements or parts which appear in the various views of the drawings will be identified by the same numbers.

With reference to Figures 1 and 2, the illustrated liquid-gas separator 10 includes a separator vessel 12 having a vertical circular cylindrical wall 14 made of metal plate and a conical roof 16, also made of metal plate. The wall 14 and roof 16 substantially envelope or surround a volume from the top to the open bottom 17.

The wall 14 of separator vessel 12 is intersected by three triangularly arranged and horizontally positioned floodable tubular buoyancy members 19 which are joined to the wall. Each tubular member 19 is joined to wall 14 and to the other to tubular members 19. Hose racks 21 are mounted on the top of tubular members 19.

Each tubular member 19 has a vertical support leg 23 (Figures 1, 5 and 6) extending downwardly from its outer end. Each leg 23 is tubular. The bottom part of each leg contains concrete ballast while the upper space of each leg is hollow and functions as floodable buoyancy chamber. The three legs 23 are dimensioned and positioned so as to fit inside of floating storage vessel 80 with clearance provided by slide guides 25 (Figures 1 and 5). A mud mat 27 is located on the lower portion of each leg 23.

Extending partially through the conical roof 16 is a gas receiving receptacle 30 (Figures 2) which has a circular cylindrical wall 32 and a hemispherical roof 34 joined to the wall 32. A circular deflector plate 36 is connected to the bottom of the receptacle wall 32 and seals the bottom of the receptacle 30. The deflector plate 36 is horizontally positioned and is substantially flat. The deflector plate 36 is supported by radially positioned spaced-apart beams 38 which extend from separator vessel wall 14 to the receptacle wall 32. The edge 39 of the deflector plate 36 is located inwardly from the separator wall 14 so as to provide a flow path 41 for oil and gas.

The lower portion of receptacle wall 32 is provided with rows of circular holes or ports 43 and semicircular holes 44 at the bottom of the wall. The holes 43 and 44 permit liquid to flow from outside to inside the lower portion of receptacle 30. Further holes or ports 46 are located about in the middle of wall 32, but beneath the upper-most part of conical roof 16, so that gas which collects beneath the roof 16 can flow into the upper portion of receptacle 30.

An oil withdrawal conduit 47 (Figure 2) is vertically positioned in receptacle 30. The lower end of the oil withdrawal conduit 47 has a conical section 48 which rests on a cross-shaped base 49 so that oil can flow into conduit 47. The upper end of conduit 47 extends through the receptacle roof 34 to an oil hose 53.

A gas flow control valve 54 (Figure 2) is mounted on the top of the receptacle roof 34 so as to be in gas flow communication with the upper interior space of the receptacles where gas can accumulate. The valve 54 is mechanically regulated by means of a lever arm 55, to which a crank arm 56 is connected, and a vertical rod 57 which is joined at the top end to the crank arm 56 and at the bottom end to a float 58. The rod 57 slides loosely in a tubular guide 59 which is held fixedly in place by a bracket 60. A stop 61 limits upward displacement of the rod 57. The float 58 floats on the surface 65 of liquid inside the receptacle 30. The receptacle provides a quiescent environment for gas-oil separation and for proper operation of the float. The level of the oil surface outside of receptacle 30 is the same as that inside it. The oil layer 66 floats on the surface 68 of sea water inside of the separator vessel 10.

Gas which is released through the valve 54 flows through a pipe connection 71, to a gas hose 72, a conduit 109, and a valve 110 to a flare conduit 112.

Access to the receptacle 30 interior is provided by a manhole 74 which is closed by a removable cover 75.

The described liquid-gas separator 10 can be used by positioning it above a sea floor well blowout 70 so that the lower ends of the legs 23 rest on the sea floor and thereby support the separator vessel 12 above the well blowout. The oil and gas mixture escaping uncontrollably from well blow-out 70 flows upwardly until it meet deflector plate 36. Since oil from subterranean formations contains large amounts of dissolved gas under pressure, much of the gas is quickly released from the oil. The gas flows rapidly upwardly around the edge of deflector plate 36 into the upper space of separator vessel 12 beneath roof 16 while displacing water therefrom and from receptacle 30. The gas flows through holes 46 into the upper space of receptacle 30. When the gas volume accumulated in the receptacle is sufficient to depress the gas-oil interface to the level of the float 58, the gas valve 54 partially opens and gas flow regulation begins, to maintain the level of the gas oil interface.

Oil also flows around the edge 39 of deflector plate 36 until the accumulation of oil 66 moves the oil-water interface 68 downwardly to the inlet elevation of the oil withdrawal conduit 47 conical section 48. Oil will begin to flow under the open end of conical section 48 and rise up conduit 47 due to the difference in specific gravity with water.

The flow of oil through oil withdrawal conduit 47 and hose 53 is self-regulated to maintain the oil layer within a predetermined comparatively narrow depth. The motive force for withdrawing the oil through conduit 47 comes from (a) the difference in specific gravities between sea water and oil and (b) the pumping action provided by gas continually being released from the oil as the pressure drops when it flows upwardly in conduit 47 and hose 53. As the oil rises from the seabed the pressure decreased

and a continuing outgassing from the oil occurs. If additional gas-pumping or lifting force is needed, a gas diversion pipe can be placed in communication with the receptacle upper interior gas accumulating space and the upper portion of oil conduit 47. The additional gas directed into the stream of oil being removed from the receptacle 12 as described can provide all the extra lifting action which may be required.

The pressures within the separator are approximately equal to those of the surrounding sea water. It is important to the operation of the separator 10 that back pressures of the gas and oil flow lines 72 and 53 respectively be significantly less than the head represented by the height of the separator.

Figures 3 and 4 illustrate a floatable storage vessel which can be used separately or in combination with the already described liquid-gas separator. The floatable storage vessel 80 comprises a metal shell having an open bottom enveloping or surrounding a volume from the shell top to open bottom. The shell has a double curved convex roof 82, made of metal plate, which joins the top of a vertical circular cylindrical inner wall 84. A similar outer wall 86 is spaced outwardly from inner wall 84. Bottom 88 extends between the bottom edges of walls 84 and 86 and top 89 extends between the top edge of outer wall 86 and inner wall 84. Access to a floodable buoyancy space between the inner and outer walls is provided by a manhole 91 which is closed by a removable cover 93. Concrete ballast 95 may be placed in the bottom of the space between the inner and outer walls 84 and 86 to provide the storage vessel with stability. Bulkheads 87 dived the space between the walls into chambers 85 which can be separately flooded.

Several conduits 97 extend completely through the walls 84 and 86. Each conduit 97 contains a valve 98 which is open during initial positioning of the apparatus over a blowout. Excessive gas trapped in the storage vessel 80 is vented through the conduits 97 before the separator vessel 12 captures the escaping gas and liquids.

A helicopter deck 100 is supported on the storage vessel 80.

Extending downwardly through roof 82 (Figure 4) is a pipe 102 having a removable cap 104. A series of spaced apart holes 106 are provided in the lower part of the pipe 102. Oil provided to pipe 102 by the hose 53, (connected to receptacle 30) spills out of the holes 106 and forms an oil layer on water in the vessel 80. Gas released from the oil, due to reduction of pressure, is simultaneously vented through the holes 106 and it accumulates in the upper part of the vessel.

Gas previously separated from oil escaping from a blowout is fed by hose 72 from the receptacle 30 to a conduit 109 which extends vertically through the roof 82. A valve 110 is placed at the end of the conduit 109. The valve 110 is closed during lowering of the separator 10 while compressed air is introduced into the conduit 109 at a point above roof 82 by a conduit 153. The valve 110 is open during horizontal positioning of the separator 12 over the blowout. Compressed air is contained inside receptable 30 by the automatic closing of the valve 54 by the float 58.

A conduit 114 communicates with the interior of a storage vessel 80 and a manual valve 116. A conduit 118 extends from a valve 116 to a shut off valve 120 from which conduit 122 extends to conduit 112. The shut off valve 120 is open when the unit is operating but it could be closed when the storage vessel 80 is not in use. The valve 116 is used to bypass a pressure relief valve 126 when necessary to equalize internal pressure. A conduit 124 communicates with the interior of the vessel 80 and the pressure relief valve 126 which operates between 0.5 to 1.0 psig. Extending from the valve 126 is a conduit 128 which communicates with the conduit 118. After the storage vessel 80 is placed on location, the valve 116 is closed, and the valve 120 is opened. As gas accumulates in vessel 80, the gas pressure increased and finally forces open the pressure relief valve 126. The gas then flows through the valve to the conduit 128, the valve 120, the conduit 122 and then to conduit 112 from which it is flared.

Oil which accumulates in the storage vessel 80 is removed by a standpipe 130 which has an inlet mouth 132 so positioned as to be at the initial oil-water interface during use of the vessel 80. The bottom end of the standpipe 130 communicates with a sump 134. A pump (not shown) is placed in the sump 134 to force the oil through a conduit 136 and thereby out of the vessel 80 for delivery to a tanker or to a burner.

Figures 5 and 6 illustrate how the already described liquid-gas separator 10 and the floating storage vessel 80 can be used in combination to capture, collect and store oil and gas flowing uncontrollably from a sea floor well blowout.

As shown in Figure 5, the liquid-gas separator 10 is initially nested inside the floating storage vessel 80. Air occupies the space in vessel 80 except for the water layer inside due to the water displacement of the apparatus. A wire rope 140 extends from the top of each leg 23 through a gland 142, then over a pulley 144 to a hoist 146. The apparatus is in this state whilst it is moved to the site of the blowout.

Prior to the apparatus arriving at the site of the blowout, three heavy anchors with sea buoys are placed at equal distances around the blowout by a conventional offshore anchor handling vessel.

The tug towing the apparatus approaches and moors to the anchor buoy up-current from the blowout and shortens its towing line 150 to hold the apparatus about 200 feet away from the blowout. At this time two additional tug/work boats with stern winches approach the apparatus, pick up messenger lines and connect to two additional mooring pendants. These tugs then move away from the apparatus and moor to the remaining anchor buoys. The apparatus then is under positive positioning control by means of the three tug winches.

The separator 10 is then disengaged from the floating storage vessel 80 by lowering the vessel 80 by flooding ballast chambers 85 until the separator 10 floats free inside the vessel 80 and towing locks (not shown) are opened. The vessel 80 is then deballasted to minimum draft (maximum freeboard)

by pumping out ballast water from chambers 85. At the same time, the separator 10 floating inside vessel 80 is ballasted to its submerged weight mode (controlled negative buoyancy) and lowered by means of three hydraulic hoists 146 and lines 140.

The separator is lowered until it is near but above the sea floor. During lowering, compressed air is pumped into the receptacle 30 to keep the separator buoyancy constant. The air is pumped in through an open valve 151 to the conduit 153 which feeds it to the conduit 109 and the hose 72. The valve 110 is closed during lowering of the separator 10. The pressurized air flows through the pipe connection 71 to by-pass conduit 157 containing check valve 159 and into receptacle 30. The air cannot be introduced through the valve 54 since the float 58 is in water and the upward force exerted by it on its associated mechanism closes the valve 54 during lowering of the separator.

Under positive control of the three tug winches, and with all valves and controls set for automatic operation, the vessel 80 is moved over the blowout. Assuming the blowout is on fire, the vessel 80 is safely moved directly into the fire and "boiling area" with little loss of buoyancy. Water may be sprayed on the vessel 80 from on-board nozzles or from a nearby ship although this is not considered necessary since the fire will be automatically extinguished as gas and oil are trapped by the apparatus.

The vessel 80, being larger in diameter, will start to collect gas under it before the separator 10. As soon as this gas builds up pressure to 1 psig the gas to pressure relief valve 126 will vent gas to the conduit 112 for flaring. The gas relief valve will be set to open at 6.894 KN/m^2 (1 psig) and close at 3,447 KN/m^2 (0.5 psig.) Assuming there is gas in excess of this valve and line capacity, the four additional relief ports 97 extending through the double wall with valve 98 open, will automatically vent to the outside.

As the separator 10 moves over the blowout, gas and oil will be trapped within vessel 12 and it will automatically function as a gas-liquid separator, with gas, at the sea depth pressure, going up the hose 72 to flare.

With the vessel 80 substantially centered over the blowout, the separator position is verified and, if necessary, adjusted by winch lines from the three tugs. Position verification may be accomplished by either diver observation or sonar devices placed at the proper radius from the blowout prior to arrival of the apparatus.

With position verified the separator 10, now operating, is lowered over the blowout until it rests on its three legs 23. Upon contact with the sea floor, flood valves are opening and the hollow legs 23 are flooded giving a total negative buoyancy of about 850 kips in the embodiment in the following example. The lowering lines 140 are slacked off to allow ample motion of the vessel 80 in various sea conditions. Now the apparatus is fully operating and valve 98 must be closed.

Additional mooring lines and anchors may now be placed and connected to the pendants which are part of positioning lines 150. Each positioning tug may then be removed and replaced by a mooring line.

As oil builds up in the separator 10 (about 2000 bbls) it will start to rise in the oil hose 53 to the vessel 80 oil, gas and water storage/separator. This movement of oil will be speeded up by some gas liquids changing to gas as pressure drops in the hose 53 (reduction of sea pressure). In the event that the gas in a specific blowout is not sufficient to move the oil through the oil hose rapidly enough, gas from the receptacle 30 of separator vessel 12 may be injected into the oil conduit 47 by a conduit not shown and remotely controlled valve therein. This valve could be backed up by a manual (diver) operated valve.

Both the high pressure gas from the separator vessel 12 and the low presure gas from the vessel 80 are vented to conduits 122 and 112 and burned. The captured oil is accumulated in vesel 80 (up to 140,000 bbls in the following example) and it can be either burned by on-board burners or pumped to a transfer barge or small tanker through a floating hose loadout system.

After the blowout is killed, the separator 10 is recovered by reversing the lowering procedure and securing it within vessel 80. The apparatus is then towed back to its storage location.

Example

A liquid-gas separator 10 as shown in Figures 1 and 2 can have a 15.24 m(50 ft) diameter vessel 12 with a vessel wall 14 which is 4.5 m (15 ft.) high and a conical roof 16 sloping 22.5°. The deflector plate 36 can be 40ft. in diameter. The receptacle 30 can be 3 m (10 ft.) in diameter and have a total heigh of 20 ft. with one-half of the height being beneath the conical roof. The tubular members 19 can be 2.4 m (8 ft.) in diameter. The legs 23 can be 2.4 m (8 ft.) in diameter and have a length of about 50 ft. and they can be set in a 45 m (150 ft.) diameter circle to straddle wreakage on the sea floor. The liquid-gas separator could have a submerged weight on lowering of 90 Kips and a submerged operating weight of 850 Kips.

The floatable storage vessel 80 can have an internal diameter at the vertical wall 84 of 48.75 m (160 ft.) and the wall 84 can be 15.25 m (50 ft.) high. Oil could be stored in the vessel for a 40 ft. depth beginning at the top 89 of the wall and extending downwardly to 3 m (10 ft.) above the wall bottom 88. The vessel could thus store about 140 Mbbl of oil. The vessel could have an initial positioning freeboard of 15 ft. with no gas pressure in the vessel, and an operating freeboard of 3m (10 ft.) with gas in the vessel at 6.894 KN/m^2 (1 psig).

The high pressure gas hose 72 can be 20 cms (8 in.) in diameter. The oil and low pressure gas hose 53 can be 30 cms (12 in.) in diameter and the pipe 102 can bw 1.2 m (4 ft.) in diameter.

The foregoing detailed description has been given for clearness of understanding only, and no unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

CLAIMS

1. A liquid-gas separator for use in the offshore capture near the sea floor of uncontrolled flowing oil

containing dissolved gas under high pressure which is released from the oil, comprising: a separator vessel comprising a shell, having a substantially open bottom; a gas removal conduit communicating with an opening in the upper part of the shell through which separated gas can be selectively withdrawn from the vessel; an oil withdrawal conduit having a lower end within the volume inside the shell and substantially below the gas opening and extending upwardly through the shell; a valve in the gas removal conduit for regulating withdrawal of gas so that an interface between oil and gas in the vessel can be maintained, within a predetermined vertical displacement, above the lower end of the oil withdrawal conduit, and means attached to the vessel for supporting the vessel near the sea floor above a source of unconrolled flowing oil containing dissolved gas.

2. A liquid-gas separator according to claim 1 including a substantially horizontal deflector plate beneath, and spaced downwardly from, the lower end of the oil withdrawal conduit.

3. A liquid-gas separator according to claim 2 in which the deflector plate is above the vessel open bottom.

4. A liquid-gas separator according to any one of the preceding claims including means in the vessel for adding air to the vessel when it is being submerged, to thereby maintain constant buoyancy during lowering.

5. A liquid-gas separator according to any one of the preceding claims containing ballast means and buoyancy means attached to the vessel giving it floatable stability.

6. A liquid-gas separator according to claim 5 including means to flood the buoyancy means to give the separator negative buoyancy.

7. A liquid-gas separator according to claim 5 or 6 in which the buoyancy means includes floodable horizontal tubular members attached to the vessel.

8. A liquid-gas separator according to any one of the preceding claims in which the means supporting the vessel near the sea floor includes legs which can extend to the sea floor when the vessel is in position over a source of uncontrolled flowing oil and gas.

9. A liquid-gas separator according to claim 8 including vertical support legs extending downwardly from at least some of the tubular members.

10. A liquid-gas separator according to any one of the preceding claims in which the vessel has substantially vertical walls.

11. A liquid-gas separator according to claim 10 in which the vessel walls form a cylindrical shell.

12. A liquid-gas separator according to claim 10 or 11 in which the walls support a conical or domed roof.

13. A liquid-gas separator according to any one of the preceding claims in which the vessel includes a centrally positioned gas receiving receptacle extending above the top of the vessel.

14. A liquid-gas separator according to claim 13 in which the gas receiving receptacle has a circular cylindrical wall extending through the top of the vessel, and a roof supported by the wall.

15. A liquid-gas separator according to claim 14 as depending upon claim 2 wherein the deflector plate is located beneath the receptacle wall.

16. A liquid-gas separator according to claim 14 or 15 in which ports permit flow of oil and gas from outside the cylindrical wall to inside the receptacle.

17. An offshore oil storage apparatus comprising: a floatable storage vessel having positive buoyancy at all times in normal operation comprising a shell, having a substantially open bottom, enveloping or surrounding a volume from the shell top to open bottom; a conduit for delivering a mixture of oil and gas to the storage vessel interior; a conduit for withdrawal of oil from the vessel interior with the vessel floating on water and containing a layer of oil floating on the water and with gas above the oil layer; and a conduit for withdrawal of gas from the vessel interior.

18. A storage apparatus according to claim 17 in which the vessel has a substantially vertical circular cylindrical wall and a roof supported by the wall.

19. A storage apparatus according to claim 17 or 18 in which the wall has buoyancy chambers to which ballast can be added.

20. An offshore liquid-gas separator, collector and storage unit, comprising in combination: (A) a floatable storage vessel having positive buoyancy at all times in normal operation comprising a shell, having a substantially open bottom, enveloping or surrounding a volume from the shell top to open bottom; a conduit for withdrawal of oil from the vessel interior with the vessel floating on water and containing a layer of oil floating on the water and with gas above the oil layer; and a conduit for withdrawal of gas from the vessel interior; and (B) a liquid-gas separator vessel comprising a shell, having a substantially open bottom, enveloping or surrounding a volume from the shell top to open bottom; a gas removal conduit communicating with an opening in the upper part of the shell through which separated gas can be selectively withdrawn from the vessel and delivered to a disposal means on the floatable storage vessel; a valve in the gas removal conduit for regulating withdrawal of gas so that an interface between oil and gas in the vessel can be maintined within a predetermined vertical displacement above the lower end of the oil withdrawal conduit; and an oil withdrawal conduit having a lower end inside of the shell and substantially below the gas opening and extending upwardly through the shell and into communication with the storage vessel interior.

21. A combination according to claim 20 in which the liquid-gas separator is nestable within the floatable storage vessel.

22. A combination according to claim 20 or 21 in which the liquid-gas separator is attached to the floatable storage vessel by means which can lower and raise the separator in water.

23. A combination according to claim 20, 21 or 22 in which the separator vessel has a substantially vertical circular cylindrical wall and a roof supported by the wall, and the floatable storage vessel has a substantially vertical circular cylindrical wall and a roof supported by the wall.

24. A combination according to any one of

claims 20 to 23 in which the separator vessel has means attached to it for supporting the vessel near the sea floor above a source of uncontrolled flowing oil containing dissolved gas.

25. A combination according to any one of claims 20 to 24 in which the separator vessel includes a substantially horizontal deflector plate beneath, and spaced downwardly from, the lower end of the oil withdrawal conduit.

26. A combination according to claim 25 in which the deflector plate is above the vessel open bottom.

27. A combination according to any one of claims 20 to 26 including means in the separator vessel for adding air to the vessel when it is being submerged, thereby to maintain constant buoyancy during lowering.

28. A combination according to any one of claims 20 to 27 in which the separator vessel contains ballast means and buoyancy means attached to the vessel giving it floatable stability.

29. A combination according to claim 28 including means to flood the buoyancy means to give the separator vessel negative buoyancy.

30. A combination according to claim 24 in which the means supporting the separator vessel near the sea floor includes legs which can extend to the sea floor when the vessel is in position over a source of uncontrolled flowing oil.

31. A combination according to claim 28 or 29 in which the buoyancy means includes floodable horizontal tubular members attached to the vessel.

32. A combination according to claim 31 including vertical support legs extending downwardly from at least some of the tubular members.

33. A combination according to any one of claims 20 to 30 in which the separator vessel includes a centrally positioned gas receiving receptacle extending above the top of the vessel.

34. A combination according to claim 33 in which the gas receiving receptacle has a circular cylindrical wall extending through the top of the vessel, and a roof supported by the wall.

35. A combination according to claim 34 as dependant upon claim 25 in which the deflector plate is locate beneath the receptacle wall.

36. A combination according to claim 35 in which ports permit flow of oil and gas from outside the cylindrical wall to inside the receptacle.

37. A liquid gas separator substantially as herein described with reference to and as shown in Figures 1 to 3 and 5 and 6 of the accompanying drawings.

38. An offshore oil storage apparatus substantially as herein described with reference to and as shown in Figures 4 to 6 of the accompanying drawings.

39. An offshore liquid-gas separator collector and storage unit substantially as herein described with reference to and as shown in the accompanying drawings.

40. Any novel feature or combination of features disclosed herein.

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